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COMPUTER BASED PREVENTIVE MAINTENANCE SYSTEM DEVELOPMENT AND IMPLEMENTATION EXPERIENCE IN EGYPT **

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Maintenance is becoming one of the most important industrial activities both in developing countries as well as in developed countries.

In developing countries, economic development has started the industrialization programmes associated with the necessary transfer of advances technology developed in industrial countries, while the developed countries have to cope with the continuous progress in the technology and advances sciences.

In both cases, more machines with complicated designs and electronic control systems are added each year to the equipment stock. As a natural result, the ratio of maintenance to production costs is continuously increasing. Also the ratio of maintenance personnel to production personnel is increasing.

Most of the industrialization and machines are not the final aim by itself, but a means to achieve certain objectives for the good and advancement as well as prosperity of the country.

However, if the machines are not kept properly and handled in a good way to give designed capacities, the final result can be a catastrophy.

It is much more important for a developing country than for a developed country to look after capital equipment and to get the maximum out of every dollar invested.

Capital is one of the most important and decisive resources in developing countries, since most of them are already in debt as a result of heavy procurement of capital equipment. They can hardly renew or replace worn equipment to cope with technological changes. It is noticed that in many developing countries, maintenance is a neglected subject. This shows that the invested capital will be wasted in poor countries, while it is much more cared for in rich countries.

It is a common belief now that most developing countries would gain more by spending relatively smaller sums on the upkeep and care of existing equipment than relatively much larger sums on new equipment.

GROWTH OF MAINTENANCE PLANNING & ORGANIZATION

The advance in the fields of science and technology results in a revolution in production techniques. More automation, transfer equipment, electronic controllers and microprocessors are used in modern plant desings.

It was a necessity for the production management to have well planned production to cope with increased volume and variety of products and as a consequence of demand of perfect quality, great advances in this field were made and production planning and control became a science in itself, with the development of new techniques and further it became one of the most important activities in each industrial enterprise.

The management attitude towards maintenance even till very recent years has been relatively not to the required level. It was considered as an activity which does not deserve any special attention and it seemed good enough to assign to it a few technicians and skilled workers to put the machine back to operation if it failed or broke.

It is not very long ago, when a technician who did not prove his qualities in the production line was transferred to the maintenance group.

The most important consideration for the management was to keep machines running irrespective of maintenance costs and complications. With the introduction of quality control, the managment realised that it is not enough to keep machines running, but they must produce within close specifications to avoid high rates of rejections. Moreover, it was realised that repair work must be done quickly and accurately to avoid long down-time together with high cost. The attitude changed, (to do the work accurately and quickly) and the concept of advanced planning for repair work was introduced by the second or thind line of management.

It was difficult to implement production plans and schedules to meet the market requirements because no one knew when the machine would break or stop. Emergency repairs represented 80-90% of the maintenance work. The sudden stoppage of one machine, could result in the stoppage of a complete production line or even the whole factory, and in addition, it could cause damage to the product under processing.

Progressively, the concept of management changed from the attitude of coping with failures after they happened, to the control of stoppage and break down.

The basic principles of preventive maintenance were first introduced insuring the planning for equipment stoppages a little before they are liable to break. The main objective was to have stoppages as planned. In this case, the management will be controlling the machines instead of the machines controlling them and thus the production plans can also be controlled.

MAINTENANCE PROBLEMS IN EGYPTIAN IRON & STEEL CO.

The Egyptian Iron & Steel Co. is the biggest industrial complex in the country. It has the only integrated steel plant in Egypt and is a vital factor in the industrial growth and economy of the country.

The plant started its production in 1958 (300,000 tons per year of steel wrought) having two sinter machines 50 m^2 each, two blast furnaces 575 ft^3 each and three Thomas converters, 17 tons each, together with blooming, heavy section, light section and plate mills.

In 1967, a hot and cold strip mill was added. The plant was expanded in 1973 to a designed capacity of 1.2 million tons having then 4 sinter machines, 75 m^2 each, two blast furnaces, 1033 ft^3, 3 L.D. converters, 80 tons each, 3 slab casters 2-strands each and 3 billet casters 6-strands each.

The plant is equipped with all utilities for oxygen, air, steam, water cooling systems, fuel and the necessary step-down electric substations.

Over the years, efforts have been intensified to achieve the rated capacity of production in the various units of the plant. One of the major bottlenecks in this has been the availability of the equipment and process facilities for production, which is primarily dependent on good and effective keeping and maintaining of the plant.

The maintenance problems have been compounded by the stringent conditions of operation in the plant, lack of spares or stocks of spares in some cases, and also largely by the highly corrosive actions due to high percentages of sodium chloride contamination in the iron ore extracted from mines of the company.

Immigration of plant staff to work outside the country and the high turnover of labour due to the willingness to increase their income also add problems to maintenance. Therefore, the production figures were affected.

The need for a well co-ordinated planning and control of maintenance management as a result of what has been described above, has been strangely felt and the maintenance problems have constantly been engaging the attention of the plant management.

A technical assistance programme with the help of UNDP/UNIDO was implemented under project Nos. DP/EGY/73/028 and DP/EGY/006, phase I to develop and establish computer based systems for preventive maintenance planning and follow-up and also for spare parts planning, production and stock control.

Encouraged by the successful results of these projects, the Egyptian Iron & Steel Company with the help of UNDP/UNIDO took up further development and implementation of computer based systems for planned repairs, on-line production planning and material tracking for mills, and process control in oxygen steel making under project No. DP/EGY/81/012.

This project also envisaged that the Egyptian Iron & Steel Company will assist other major engineering and metallurgical industries to implement similar systems for maintenance management and conduct training programmes covering maintenance management systems and practices for engineers for the countries of the African region.

The project included in its scope the establishment of a Centre of Excellence Metallurgical and Engineering Industries at the National & Regional level.

The major subsystems

The chart opposite gives the schematic view over the total Maintenance System.

Preventive maintenance and planned repairs proved to be very successful tools in reducing down-time and maintenance costs. It is very important for preventive maintenance planners and programmers to be well acquainted with possible equipment performance under local working conditions. This would enable them to determine when the machine must be stopped long before any failure occurs.

The support for the planners are the following:

1. Building of adequate records for the past performance of equipment and establishment of an efficient feedback system.

2. Use of predictive maintenance employing modern measuring equipment for noise, vibration, crack detectors, etc.

These methods will help avoiding surprises. Such detectors proved to be very useful tools and not expensive to buy. Visual inspection alone is far from being enough and the adaptation of monitoring techniques indicating physical changes would give lead to better results in maintenance work.

Good planning and adequate repair have the following aims:

1. Maximum possible availability and readiness of equipment for production.

2. Longest possible life time of equipment and spares.

3. Minimum maintenance and running costs.

4. Helps for preparing standardization on plant level and consequently reducing production costs.

Equipment reliability and maintainability both together determine the availability of equipment for production.

In plant layout, enough attention should be given to equipment accessibility so it can be reached and maintained easily.

When failure occurs, it is not enough to repair the equipment, but is is much more important to study carefully the reasons of failure, in order to either eliminate it completely in the future, or at least to prolong the time between failures.

A highly experienced technical group must be established on plant level or in each productive area to study and analyse reasons for failures.

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Due to such studies, they can study some changes in the equipment itself or hire specialized engineering firms for such changes to eliminate defects.

The cost of maintenance during the life time of industrial equipment will vary from 80-300% of the initial cost.

Equipment reliability should be considered carefully and the optimum level balancing the cost of increasing equipment reliability against gains due to increased availability combined with the cost of maintenance must be decided. Increasing equipment reliability means in most cases incrceasing initial costs. A point is reached where further increase in the equipment cost due to increasing reliability will not be met and matched by an equivalent decrease in maintenance cost or increased profitability of the plant.

This level is much affected by local conditions. In many developing countries where skilled workers are not available easily and spare parts are expensive or difficult to get, it may be a wise policy to look for a higher level of reliability with high initial cost. Saving in initial cost does not means only increased maintenance costs but also a great loss in production. The more expensive equipment may prove to be the cheapest in the long run.

PLANNING MAINTENANCE WORKS

Maintenance works can be classified into three major categories:

1. Preventive maintenance including use of predictive maintenance techniques.

2. Planned repairs programs.

3. Capital repairs programs.

Planning maintenance work for a certain group of equipment as follows:

Preventive maintenance

The application of F.I.T.C.A.L. principles which means:

F	=	Feel
I	=	Inspect
T	=	Tighten
C	=	Clean
A	=	Adjust
L	=	Lubricate

The maintenance schedule and planning will entail the operation to be carried out in full details and its frequency and the time required for each operation.

The main objective of this type of maintenance is to keep the machine in good working condition without the need to stop it for any operation unless it is an obligatory case.

Maintenance will be:

a) Feeling the temperature of all bearing points and sleeves and other sensitive parts of the machine and identifying abnormalities.

b) Inspect the machine for eccive noise and vibrations, reading all measuring instruments and dials.

c) Tightening all screws and nuts.

d) Cleaning the machine and surroundings to be able to detect any oil leakage.

e) Adjust the levels of oil tanks to the optimum level and any adjustment not necessitating stoppage of the machine.

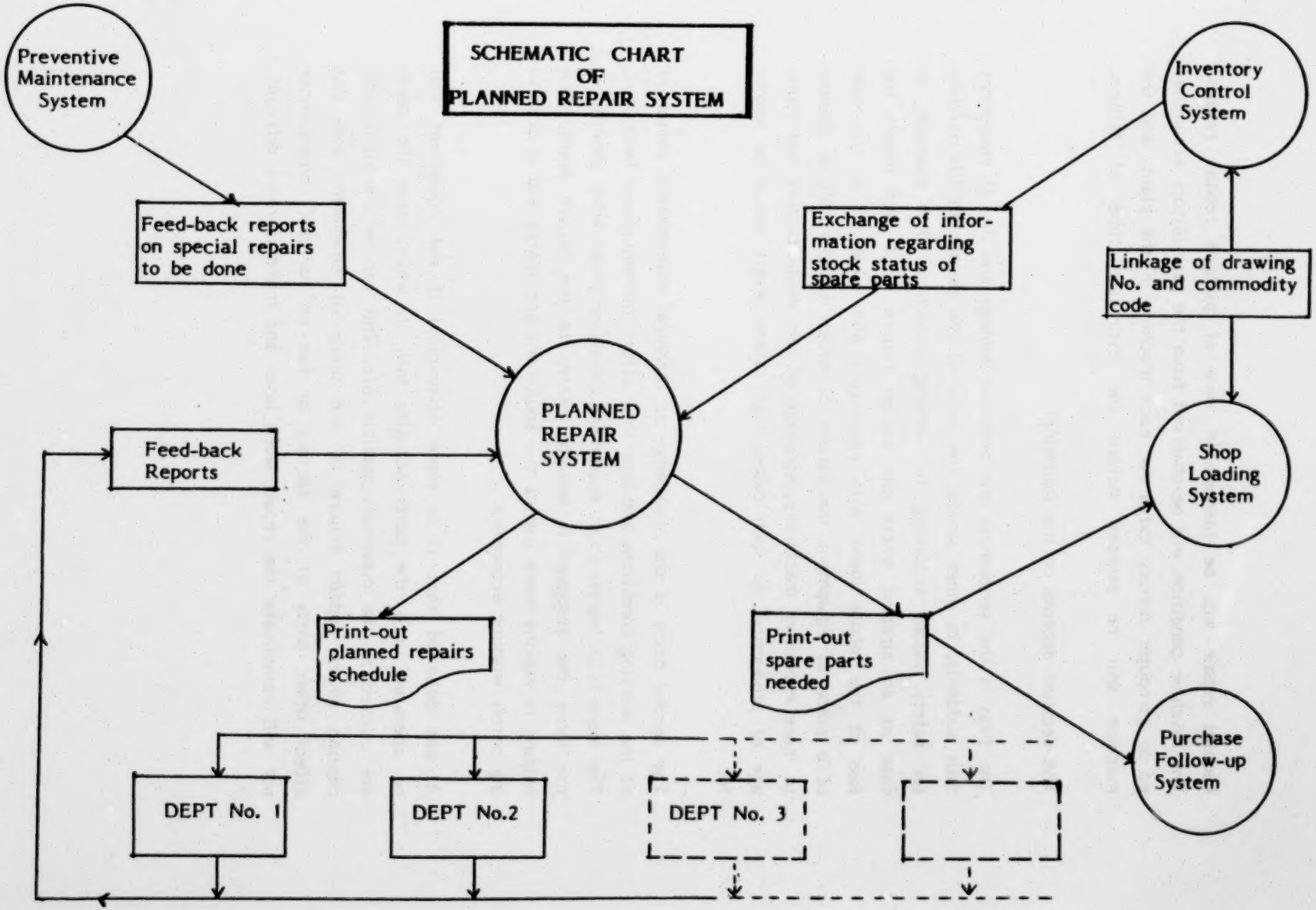
f) Lubricate all bearing points with the right quality of lubricant.

Planned repairs

Please refer to the schematic chart Fig. 1.

The inspection work done for preventive maintenance will result in reworks and recommendations, which will constitute a part of the planned repairs program with a second part previously prepared as yearly requirements of the plant. Planned repairs will be done at week-end stoppage or in between shift changes when ever all maintenance requirements become available, i.e. spares required in quantity and quality in maintenance locations, the required manpower in number and also auxiliary equipment.

FIG. 1


SCHEMATIC CHART
OF
PLANNED REPAIR SYSTEM
Preventive Maintenance System
Inventory Control System
Feed-back reports on special repairs to be done
Exchange of information regarding stock status of spare parts
Linkage of drawing No. and commodity code
PLANNED REPAIR SYSTEM
Feed-back Reports
Shop Loading System
Print-out planned repairs schedule
Print-out spare parts needed
Purchase Follow-up System
DEPT No. 1
DEPT No.2
DEPT No. 3

Capital repair will be planned in view of planned repairs results. The machine condition will be observed from the past history accumulated in computer history cards for each machine in the plant, and the machine will be stopped before the estimated time of failure.

The decision depends on the following:

The first is the seriousness and probable damage and loss if equipment fails suddenly. In other words, the ratio of the equipment life scrified for safety varies according to working conditions. For example, in case of an airplane where the sudden failure of a part means the loss of the whole plane with passengers and crew, or in the case of a piece of equipment the failure of which would result in damage to more expensive machinery, stoppage of the whole factory and spoilage of production. In such cases, high safety levels should be looked for.

The second point is the knowledge of technical maintenance personnel of the working conditions and how they affect the equipment behaviour. The more it is known about equipment behaviour under work conditions, the more the stoppage is brought nearer to the failure point, thus helping in making more use of the equipment and spares and in achieving better working economics.

It was believed that it is more economical if the equipment will be operated until the parts actually fail, in which case the parts are utilised to the maximum possible life. This can be the right conception where sudden failure of one piece of equipment does not affect other parts of the factory or has no harmful consequences nor will complicate the repair work later and make it more difficult.

A very important part of maintenance planning and management is determining which machines will be allowed to work until they actually fail and which equipment should be stopped according to a plan, some time before failure is anticipated. It is advisable to consult original manufacturers of equipment when necessary.

THE COMPUTER BASED SYSTEM

The main core of computer based maintenance is the preparation of a well coded master file for equipment and duties to be performed. This will be done as follows:

As mentioned before, it is important to maintain equipment history cards for each piece of equipment as shown in Fig 2, such a record will help in studying the behaviour of equipment and the effect of improvement and frequency of preventive maintenance and planned repair, proper planning of spares and analysing the past performance of the equipment, i.e.:-

1. Any failure that takes place and how it was set right.

2. Repairs and overhauling jobs done.

3. Parts replaced, or any alteration in design, material or heat-treatment performed and life due to that.

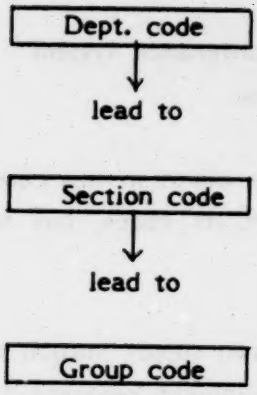
4. Any other major work or modification done.

To obtain maximum value of these cards, it is essential that these are filled regularly and to be reviewed periodically by the maintenance engineer in charge.

Steps of Implementation

- Divide the plant into its main departments or production lines and we call it equipment site plan and define a code No. for each department as shown in Fig. 3.

- each department is to be divided into a definite number of section codes and each section code to be subdivided into groups codes.



- as stated before in P.V., we state all operations of maintenance to be written in a special form as in Fig. 4 which is the input format.

How to use input formats:

- write down: Dept. code in column 4 - 5
  Section code in column 6 - 7
  Group code in column 9 - 11

- in column No. 8 we state the type of maintenance.

Type of maintenance:

There are 3 codes for type of maintenance in our system:

Code 1 for mechanical activities
Code 2 for electrical activities
Code 3 for instrumentation activities

When you are preparing preventive maintenance system for electrical activities, you will face three conditions:

1. A power station, for example, in a plant, in this case one consider it as a separate department with its codes, but to use code 2 in column 8.

2. A production department has its own supply station or transformer room, or any other electrical equipment separate from the main production line. In this case, there will be no change in department code No., it will be the same for the mechanical and electrical groups. But the difference will be in section code and its own group codes, mechanical have code 1, and electrical code 2.

3. When we face a unit with a combination of mechanical and electrical in our section code (e.g. a rolling machine coupled with electric motor) in this case, we can use two alternatives either A or B:

   A) Under the same section code we can use a group code for rolling machines and another group for the electrical part and when we prepare sheet input format, we use the same department code, and the same section code, the change will be only in column No. 9 to 11 group code column, and secondly in the column No. 8 we use code 1 for mechanical activities and code 2 for electrical.

   B) We can use the same group code for these combination of mechanical and electrical equipment but it must be divided up in such a way that the mechanical and electrical equipment is kept separate by using column No. 8.

An example of case B, machine tools, cranes, compressors, etc. and the two activities to be done in two separate input sheets.

The work is to be continued until we finish all groups of the sections and then all section of department.

We have to remember that when preparing the code numbers of one department, section code will have 2 digits starting from 10-90 while group code will have 3 digits starting from 001-999.

YOU CAN FOLLOW ONE OF THE FOLLOWING METHODS WHEN PREPARING THE SECTION CODE AND GROUP CODE:

1. Under the first section code in the department you can start with code 001 and continue to number the group and of the last group code is 027, then when starting to number the section code, the first group code can have No. 028 and so on until you finish all the sections.

2. Alternatively, you can follows another system, i.e. in the first section code you can start from 001 and if the last group code No. in the first section is 027, then when you start the second section code in the department you can start with the first group code No. as 001, again until you finish the second section code and also in the third section code you can start again with the first group No. as 001 until you finish all section codes.

IN ALL CASES:

1. Never mix the first method with the second one in the same department.

2. Never use more than 2 digits for department code; 10, 20, 30, - 90, and also for section code starting from 10 - 99.

3. Never use more than 3 digits for group code in one department in the first system or in the section of the second system starting from 001 to 999.

How to prepare preventive maintenance data in input form

1. Each line in the form corresponds to one separate activity in the planning of preventive maintenance, i.e. every line must represent one card if you will use manual system.

2. All preventive maintenance items must be written in input form for every group code.

3. If one item in the sheet needs more informations to do, the recommended preventive maintenance activity can be specified on separate instruction sheet. These instructions are normally based on the manufacturer's manual instructions and on the experience of the maintenance crews in the company and also from the history of information kept in maintenance department for the past years.

4. Separate instructions should be serial - numbered and these numbers must be mentioned in input form for the item which will need those instructions.

5. These instructions will not be kept in the preventive maintenance file in the computer disc. Only instructions code number will be kept for reference.

6. The instructions must be printed in specified number of copies and distributed to the personnel who will carry out the preventive maintenance system in the field.

Data for identical items of the same type

In case of identical equipment of the same type in a department, this equipment may be in the same section or in different sections. But in both cases, we must use the same preventive maintenance data in form Fig. 4 to facilitate preparation of data for computer files. The following procedure may be adopted:

First case

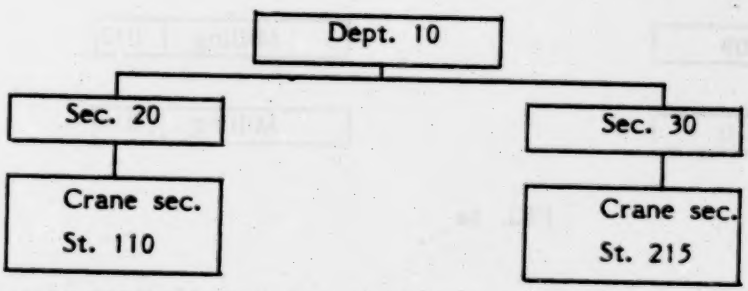


FIG. 5

Suppose we have 2 identical cranes of 5-tons capacity in two different sections, 20 and 30 as in Fig. 5, we can prepare the preventive maintenance sheet for one crane only in details, and only department code column 4-5 will be filled - section code and group code to be left blank, a table to be attached to the data sheet:

Sec. code	Group code
20	110
30	215

This table will indicate to the personnel of data entry in the computer department that the attached data will be repeated in department code 10 in section code 20 and group code 110 together with section code 30, and group code 215.

Second case

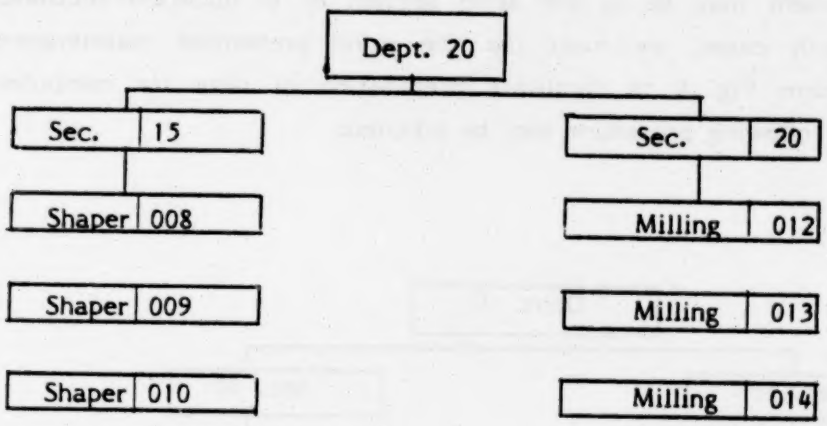


FIG. 5a

Suppose in machine tools shop we have in section 15 three identical shapers and also in section code 20 three identical milling machine as shown in Fig. 5a, in which case we can prepare the preventive maintenance sheet for one shaper in section code 15 in form Fig. 4. Department code, section code in columns 4-5 and 6-7 will be filled but group code is to be kept blank and we will attach a table in form Fig. 4 for one shaper.

Sec. code	Group code
15	008
	009
	010

This means that in section code 15 data for shaper will be repeated for the same identical machines with group codes 008, 009, 010. The same is to be applied for the milling machines.

Special case

If we have the same identical equipment but in different departments and different sections, as in Fig. 5c.

In this case, also one crane, for example, in a similar manner we just prepare one copy of the preventive maintenance sheet in Fig. 4 and state in this form the department code, section code, group code blank and attach a table as shown below:

Dept. code	Section code	Group code
10	10	010
	20	025
20	30	030
	40	035
	40	040
30	50	060

This means that for data entry personnel, that in dept. code 10 this data will be repeated in section code 10, 20 under group codes 010, 025 and in department code 20 for section code 30, 40 data will be repeated for group code 030, 035, 040 and also for department 30, section 50 data will be repeated for group code 060.

FIG. 2

EQUIPMENT HISTORY CARD

No.

Dept. ..... Name : .....

Sec. ..... Unit No.: .....

Date	Work to be done	Down time	Parts replaced	Part life		Improvement or modification
				Original	if due to change	

FIG. 3

CODE NUMBERING OF DIFFERENT DEPARTMENTS IN THE PLANT

Series No.	Department No.	Code No.
1	Department 1	10
2	Department 2	20
3	Department 3	30
4	Department 4	40
5	Department 5	50
6	Department 6	60
7	Department 7	70
8	Department 8	80

G. 4

Dept. code	Sec code	type of maint.	group code	alterat. code	start week
4-5	6-7	8	9-11	16	79-80

Line No.	freq-uency	Preventive Maintenance Activity	Part No.
13-14	15	75	76-78

FIG. 5A

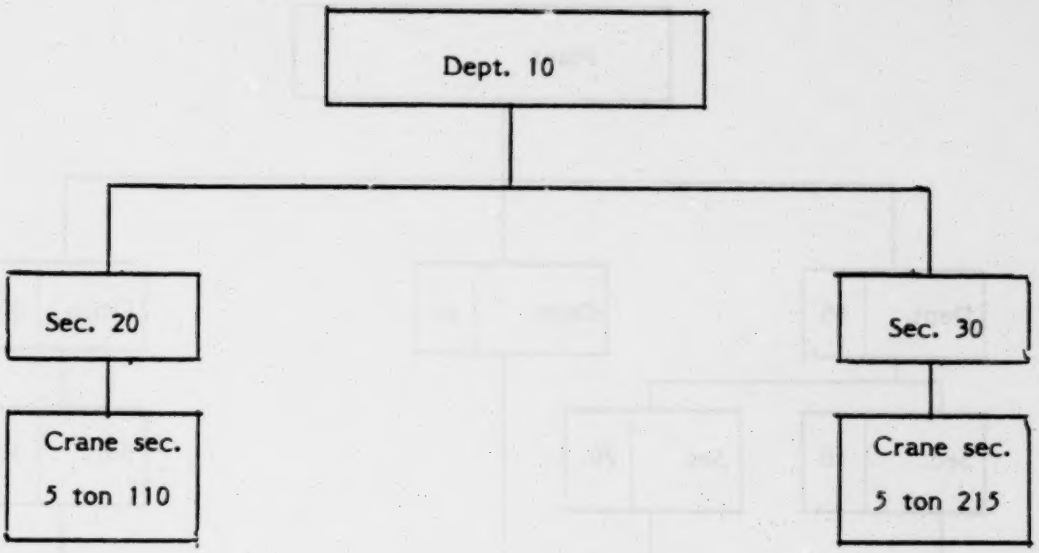

Dept. 10
Sec. 20
Sec. 30
Crane sec.
5 ton 110
Crane sec.
5 ton 215

FIG. 5B

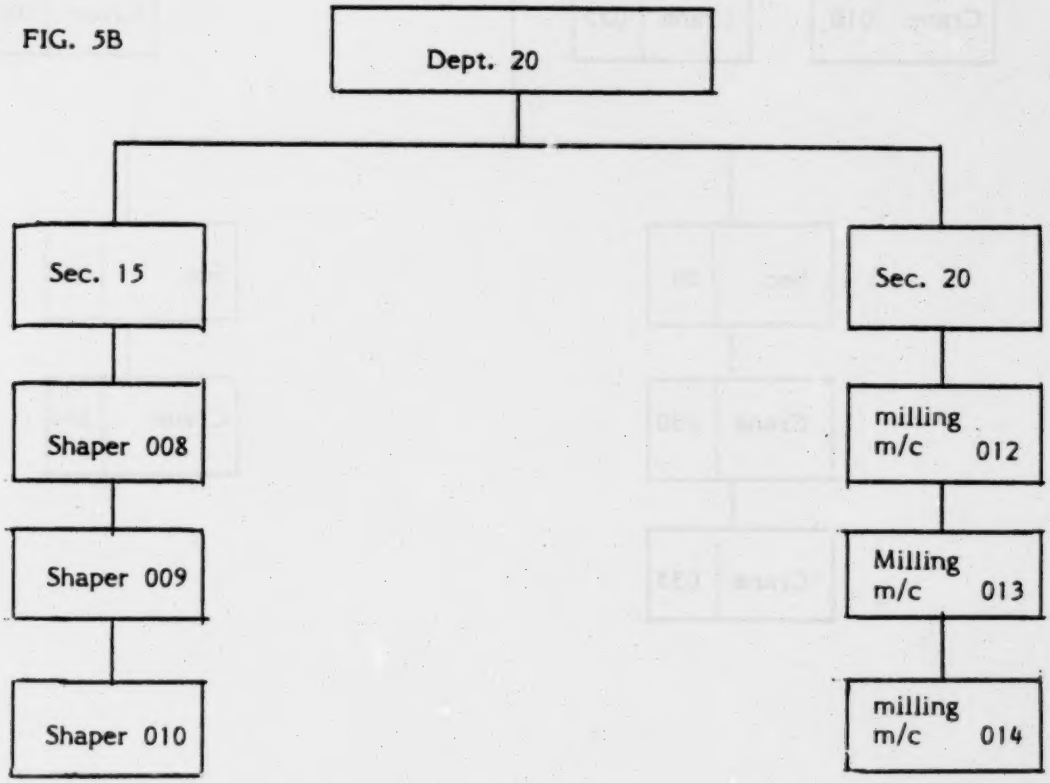
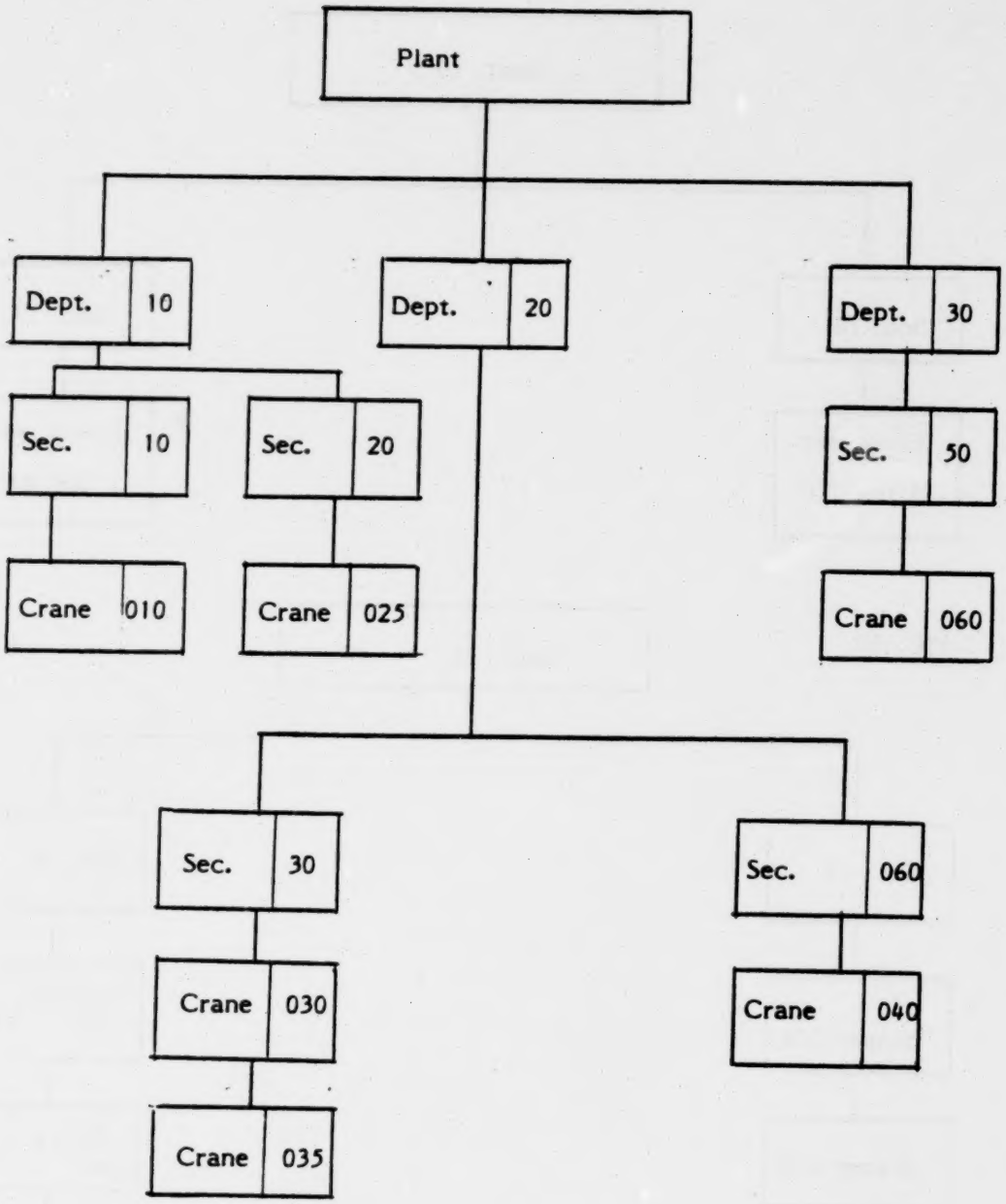

Dept. 20
Sec. 15
Sec. 20
Shaper 008
milling
m/c 012
Shaper 009
Milling
m/c 013
Shaper 010
milling
m/c 014

FIG. 5C


Plant
Dept. 10
Dept. 20
Dept. 30
Sec. 10
Sec. 20
Sec. 50
Crane 010
Crane 025
Crane 060
Sec. 30
Sec. 060
Crane 030
Crane 040
Crane 035

Frequency of maintenance

This means when the periodic maintenance job is to be done and this actually depends upon manual instructions or experience of the personnel crews in maintenance and the condition of the machine itself.

In all cases, every line of forms input must have its frequency code which is stated under column 15.

Code of frequency of preventive maintenance is shown below.

Code	Frequency
1	Weekly
2	Bi-weekly
3	Monthly
4	Quarterly
5	Semi-annual
6	Annual

Points to be considered

1. If the system is run by computer, it is better that daily and weekly activities are written separately and given to assigned maintenance to be done automatically.

2. Control of maintenance is very important, it means the activity should be done when it is necessary. This will save man-power, material and effort. Too much maintenance is as bad as not attending to maintenance. So it is very important to decide the correct frequency.

3. It is recommended to observe the result of applications of preventive maintenance, if deviations appear in the stoppage equipment, it means that the frequency of the activity should be shortened by reducing the frequency code.

4. To be able to realize the good results, a record should be kept of the information of faults to improve the preventive maintenance that means reducing maintenance costs.

5. Responsibilities of the people in charge of maintenance should be well defined either assigned maintenance or central maintenance.

Master file

To build the master file in the computer, all data about equipment and the information of preventive maintenance will be stored on the magnetic tape or magnetic disc in the computer and then we can get the output which is the master file.

This master file must be checked for any error and corrected. After data is organised in the master file, the preventive maintenance output reports will be prepared according to frequency, and sent to the concerned departments.

Feed back

All preventive maintenance groups in all production & auxiliary departments are to submit the feed back to Computer with all completed operations. The Computer will issue for the second maintenance the uncompleted jobs with a special notice so that it will not be forgotten.

In case maintenance groups do not complete some jobs for some known reasons, this is to be denoted on the Feed Back form as stated in Fig. 5 D.

PLANNED REPAIR SYSTEM

Planned repair also termed as planned preventive maintenance (PPM) or scheduled preventive maintenance, is carried out in order to keep all items of the equipment in good running order and increase their reliability, improve standard of workmanship in maintenance and repair jobs and consequently cut maintenance cost.

Types of repair under planned repair system

The main types of the repair under the P.R. program are running repairs and major repairs.

Coming under the heading of running repairs are all those items of work which involve renewing of rapidly wearing out components, cleaning, changing oils, renewing mounted hardware, reconditioning of bearings and journals, etc.

A major repair project is one involving complete dismantling, cleaning, washing, renewing, reconditioning of certain main parts, reassembling, adjusting and testing ..

Planning, organizing and conducting repairs

The data collected from routine inspections and surveys of the equipment and reported by the personnel who operate it provide the basis ror planning the repairs. This will be in addition to standard repairs to be carried out in the equipment. (This is the feedback data from the preventive maintenance). The actual scheduling of repair jobs is done on the annual basis and then divided to quarterly and monthly plans. This monthly plan may include certain items in the plan but is to be directed from inspection of P.V. program beside preparing spare parts required for such repair.

Progress reports and repair records

The monthly repair progress report is covering the following items:

1. Repair progress
2. Running repair expenditure
3. Fixed assets upkeep ecpenditure
4. Non-completed scheduled repairs
5. Completed non-scheduled repairs
6. Completed emergency repairs
7. Delayed repairs
8. Non-scheduled downtime
9. Scheduled down periods and their causes

The monthly repair reports of production shops are used for analysis and recording of the repair activities for taking the necessary corrective actions and stating initial data for cost calculations since the problem of economy in repair is given top priority at present.

SHOP SCHEDULING SYSTEM

Objectives

1. To provide the plant operating departments with workable and effective procedures for submitting requests for services and priority requirements to the plant central maintenance organization.

2. To provide the plant central maintenance department with consistent and effective procedures for:

   - planning and processing shop work order.
   - arranging work orders in a manner providing optimum treatment of plant priorities.
   - scheduling work order in a manner providing maximum utilization of maintenance labour and facilities.

3. To provide plant management with an effective tool that will minimize maintenance delays to operating equipment and enhance optimum production performances.

Procedure

Requirements of spares received from different departments of the plant in the planning central department are sub-grouped and sent .o technological offices of workshops for technical studies. Machine time is calculated and stated in a special form as in Fig. 6.

All technical data required for the manufacture of spare parts are stated in another form, Fig. 7, its explanation is as follows:

Drawing No.: - series of numbers on the drawing
Part No.: - part, identified on that drawing
Sheet No.: - page No. of drawing

FIG. 6

Order No. :

SHOP SCHEDULING PROGRAM

Machining Time

Serial No.	Drawing No.	Part No.	Description of Process	Horizontal lathes				Vertical lathes			Boring m/c		Planning m/c		Shaper m/c		Milling m/c		Hopping m/c				Plano-mil	Grinding m/c	

FIG. 7

SHOP SCHEDULING PROGRAM

Process Technology Sheet

Serial No.	Drawing No.	Parts No.	Sheet No.	Code No.	Weight/ piece	Grade of material	Form of material	Tools code or pattern code	Machine or group code	Working time hr/ piece	Type

Code No.: - first two digits define the workshop doing the required processing,

Digits 3 and 4 define the department ordering the part.

Digits 5-9 are the sequence number for the technology card.

Weight/piece: - weight of the part after processing in each shop in tons and kilograms.

Grade of material: - this is the steel grade, type of cast iron, brass, bronze, etc. It is a four digits code that identifies the grade in German and Russian standards.

Form of material: - General classification of raw material:

1. Forged parts
2. Casting parts
3. Structural parts
4. Rolled parts
5. Forged section

Tool or pattern code: - all special tools as dies or fixtures or patterns etc.

Machine or group code: - the machine or group of machines that will perform jobs.

Working time/piece: - this is in hours and consists of equipment time or group time.

Type: - this signifies an original card or a replacement card for changing information already in the master file, the type codes are listed below:

1. New card or original submitted
2. Replacement of information
3. Operation added
4. Delete an operation
5. Completed operation
6. Operation not required to be performed

Types 5 and 6 are for report completed operations.

After all jobs are collected and put in proper sequence, they should be loaded into the computer and catalogued as a master file. A printed list of this master file should be sorted for maintenance planning. The listing should be sorted numerically by print or drawing No. and a new listing made at the end of each month to give the maintenance planning office an up to date with all new jobs included.

The program as actuated by Execution card, Fig. 8. Each order will have its own card identifying the drawing No., the part No., page No., and the number of parts ordered. The date, the order to be finished is also put in this card. This will help the individual shop in determining their priorities. The computer having all technical data will calculate according to program material required, type and form of material.

SHOP SCHEDULE PROGRAM

FIG. 8

Execution Card Layout

Card code (3)	Drawing No. No. (25)	Part No. (3)	Page No. (2)	Quantity ordered (4)	Date required (8)

All shops either feeding or finishing should be required to submit daily the completed operations. The incompleted operations or backlog must be kept under control. Decision to work out the backlog to be taken, either by overtime or rescheduling as emergency or utilising equipment of other shops.

When feedback will be done by terminals, we can know directly the situation of each order.

INVENTORY CONTROL SYSTEM

Objectives

The overall objective of the spares program is to have the right quantity and quality of spares available when needed to avoid costly operating delays in production facilities and to achieve this objective with a minimum investment in spare parts.

The specific objectives are:

1. To carry in stock the minimum number of spares required to assure uninterrupted operations of works production and support facilities.

2. To tag or otherwise mark spares for easy identification.

3. To stock spares in an orderly and adequately protected manner in a minimum number of areas having controlled access.

4. To locate the right spare promptly when needed.

5. To identify and dispose of obsolete and surplus spares.

6. To adopt and use a sound procedure for replenishing depleted stocks.

7. To adopt and use a practical system for maintaining spares stock records.

Responsibilities

The Production Department's primary responsibility is to produce quality products at a maximum production and at minimum cost. A program of proper and timely maintenance of facilities minimizes production delays which are due to equipment failures. A good spares program is vital to good maintenance and thus it is an important factor in effecting the Production Department's primary responsibility.

The responsibility of the Production Department with respect to the spares program includes the following:

1. To establish reorder points and reorder quantities for spares to be carried in stock for each application, and review such data periodically for the purpose of recommending necessary changes.

2. Provide stocking facilities and protection including controlled access where practical.

3. Provide the necessary manpower to execute the program including such activities as identifying and tagging existing spares, reordering and stocking for the purpose of maintaining perpetual stock records.

4. Participate with Accounting in scheduling and taking physical inventories of all spares over a one-year cycle.

5. Make prompt decisions related to placing orders for replacements.

The responsibilities of the Accounting Department include control of all inventories. In the case of spare parts, the Works Accounting Manager's responsibilities are:

1. To see that all established spares control procedures are put into effect and that such control is continuously exercised by designated personnel.

2. To particiape in taking one-year cycle physical inventories of all storage areas.

3. To provide data processing services as required.

In order to facilitate recrod keeping and to provide a basis for accumulating and summarising various kinds of information and data, a computer based mechanical program for maintaining perpetual stock records has been developed and installed. This program is called Mechanical Spares Control. It is a recommended method of maintaining stock records for spares control.

Mechanical Spares Control

The Mechanical Spares Control Program utilizes three basic computer output documents and the travelling requsition, Fig. 9, to provide Works personnel with the basic data needed to meet the onjectives of the Spares Program. In addition to these documents, there is a number of optional computer outputs analytical reports, and catalogued listings that are available upon request. All required computer input data is recorded on one of two standard forms, Fig. 10.

Basic computer output documents

1. Spares stock record:

   The Spares Stock Record is printed annually for all items in the master file and weekly for all items with activity (cumulative) since the last annual printing. The report will be printed in one of three sequences: a) storage are by Commodity code, b) storage area by Local code, or c) Commodity code by storage area. Data furnished on the Spares Stock Record are:

   a) Commodity code
   b) Unit of measure
   c) Local code (blueprint and mark)
   d) Description
   e) Storage area and location within storage area
   f) On-hand balances for usable and repairable spares by stock location and total for commodity.
   g) Quantity on order (including new purchase requisitions and repairable items that have actually been sent to shops for repair).

h) Danger point
i) Reorder data (order quantity, reorder point and code).
j) Year-to-date activity (quantities received, dibursed, scrapped, and inventory adjustments).
k) Last disbursement date

2. Stock Reorder List .

The Stock Reorder List is published weekly and is divided into two sections;

Section A; Critical spares (Reorder Code 1) that have reached the reorder point and should be reordered immediately. Spares are considered at the reorder point when the quantity on hand plus the quantity on order is at or below the reorder point. These items will be repeated on the Stock Reorder List each week until ordered, until the reorder point is changed, or until the reorder code is changed from 1 (critical) to 2 (less critical). Before any item is reordered a review based on actual experience should be made to determine if the reorder quantity, reorder point, or quantity on hand should be changed to reflect actual usage.

Section B; Less critical spares (Reorder Code 2) that have reached the reorder point but are to be ordered only after review. Spares classified as Reorder Code 2 will appear on this report whenever a disbursement is reported for an item that is at or below the reorder point and/or at the review date in the master file (the review date serves as a reminder file enabling the Manager to delay purchase decisions). Items appearing in Section "B" of this report will not appear on subsequent reports until another disbursement is reported or until activitated by an updated review date in the master file.

Stock Reorder Lists should be reviewed by Department Managers or other responsible personnel for the purpose of indicating whether items are to be reordered or not, and whether changes are to be made in order quantities, reorder points, reorder codes, and/or new review dates established. After this review, the spares clerk will process travelling requisitions for items to be ordered and data changes for other items as noted.

Data furnished on the Stock Reorder List are:

a) Commodity code
b) Unit of measure
c) Local code
d) Description
e) Storage area
f) Quantities on hand (usable and repairable)
g) Quantity on order
h) For items that have reached the Danger Point
i) Normal order quantity
j) Consumption history for past 2 years' period:
    1. Current quarter
    2. 1st prior quarter
    3. 2nd prior quarter
    4. 3rd prior quarter
    5. Total of next 4 prior quarters
k) Last purchase order on which the item was bought
l) Last unit cost reported
m) Section A; the number of weeks reorder Code 1 spares have appeared on the Stock Reorder List, Section B; an asterisk (*) for items which are listed because of a review date in the master file.

3. Monthly Spares Summary;

The Monthly Spares Summary summarizes spares activity for the month to Egyptian Pounds, and can be used for management control and trend data analysis. Data furnished in the Monthly Spares Summary are:

a) Storage area and title

b) L.E. balance - this month and previus month (L.E. balance includes only usable items on hand. Repairable items are at no value until repaired, at which time they are transferred to usable category).

c) Current month's values for receipts and disbursements.

d) Value of items scrapped and/or sold.

e) Value of adjusted items and number of occurences for which inventory adjustments were processed.

f) Memorandum value of repairable items (value if items were in usable condition).

g) Value of items on order (new items plus repairable items actually sent to shops for repair, at new item unit costs).

h) Surplus stock values (surplus stock is usable stock on hand which exceeds the reorder point plus reorder quantity).

j) Price adjustments - the amount of L.E. balance change that results from changes in unit cost.

4. Travelling requisitions;

The method of reordering spare parts is through use of the travelling requisition. The use of this form eliminates the necessity of writing or typing purchase requisitions each time an order is placed.

The travelling requisition file also serves as an order catalogue file since it contains the complete order description and reorder data and provides a historical record of purchases. Other information such as number of units in service, etc. can also be noted on this form.

5. Optional computer output documents;

The following analytical reports and special catalogue listings are available on a request basis. Requests are made on the appropriate Report Request Form (depending on the sequence selected for the Spares Stock Record) and submitted with the Computer Input Documents.

1. Surplus Spares
2. Spares uninventoried in last (specify) months (Exhibit F).
3. Spares consumption history
4. List of spares with no usage for (specify) months
5. Spares usage by facility trend data
6. Spares inventory adjustments (monthly detail) (Exhibit 3)
7. Catalogue listings:
   - a) by alphabetic description
   - b) by commodity code
   - c) by local code
   - d) by interim class code
   - e) by storage area
   - f) by equipment code

PREVENTIVE MAINTENANCE SYSTEM

FEED-BACK SHEET

DEP code	Sec code	Type	Loop No.	Line No.	cause	week No.

DEP code	Sec code	Type	Loop No.	Line No.	cause	week No.

Code	Reason
1	Lack of Lubricants
4	Lack of Labours
5	Non stop of production
6	Stoppage of M/C for long time
7	Lack of tools and material
8	Post-poned for big repair

Code	Reason
11	Planned maintenance
14	Mechanical maintenance
15	Starting next week

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DEVELOPMENT AND IMPLEMENTATION OF COMPUTERIZED MANAGED MAINTENANCE SYSTEMS -VOEST-ALPINE EXPERIENCE **

Prepared by

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W. Pilz

*Organized by the United Nations Industrial Development Organization (UNIDO) in co-operation with the Institute for Automation and Industrial Management (INORGA-PRAGUE) under the auspices of the Czechoslovakian Ministry of Metallurgy and Heavy Engineering.

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*** VOEST-ALPINE Industrial Services, Austria

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1. VOEST-ALPINE

The VOEST-ALPINE concern is fully owned by the Österreichische Industrieverwaltungs-Aktiengesellschaft, which is owned by the Federal Republic of Austria.

Organisation and Areas of Activity

VOEST-ALPINE is structured into 9 divisions (4 central and 5 production) and has approximately 60 affiliated companies in Austria and 80 affiliated companies outside of Austria.

Division	Areas of Activity
General	General Secretariat, Central Marketing, Trading and Wholesales
Finance	Treasury, Controlling
Administration	Personnel, General Administration and Procurement
Mining and Research	Mining (iron ore, coal, wolfram), Provision of raw material, Research and Development, Quality Control
Metallurgy	Flat and non-flat rolled steel products

Division	Areas of Activity
Processing	Foundry, forged products, tubes and pipes, wire, rope, cold processed profiles, tools, movie cameras
Finished Products	Machinery for mining, workshops, industrial robots, Transport equipment; vessels, cranes, rails, buildings, compost plants turbines, heat exchangers, tanks, pipelines, boilers, components for nuclear power plants
Engineering & Contracting	Metallurgical plants, chemical plants, food processing plants, clinics and hospitals, training, technical and management assistance, energy conservation
Electronics & Automation	Process control systems, microprocessors, boards for integrated circuits, commercial and technical software, computer components

Statistical Data 1983

Turnover:	in bill. Austrian Sch.
Metallurgy	26.3
Processing	10.3
Finished Products	13.4
Plants and Services	22.9
Trading	46.3
Total:	119.2

Employees:	
Worldwide	72,288
Austria	67,677
Mother Company	39,179
Affiliated Companies	28,498

2. METALLURGICAL PLANT

2.1 Metallurgical Plant - Linz

Plant Type	Plant Description	Capacity/year	Eng.
Coke Oven	8 Blocks	1,732,000	Otto, Didier, Still
Sinter Plant	5 Sintering strands	4,400,000	
Blast Furnace	1 x 7m hearth diameter	465,750	
	3 x 8m hearth diameter	603,750	
	1 x 11m hearth diameter	1,836,000	VA
LD Plant	2 x 52t	1,396,000	VA
	2 x 130t	1,545,000	VA
Continuous Casting	2 x for slabs (LD2)	1,200,000	VA
	2 x for slabs (LD3)	1,500,000	VA
Electric Arc Furnace	2 x 20t	75,300	
Heavy Plate Mill	Four high stand	650,000	Möller Neumann Krupp
Hot Strip Mill	1 Roughing Stand 7 Finishing Stands	2,490,000	Demag Mesta VA
Cold Rolling Mill	1 Four high reversing Mill		VA
	1 Four high reversing Mill	517,500	VA
	1 Sendzimir Mill (Z Mill)		VA
	1 Tandem Cold Mill	802,500	VA

Plant Type	Plant Description	Capacity/year	Eng.
Hot Strip Galvanising		141,400	Heurty
Foundry	Steel castings 3 - 70t (100 t max)	7,000	
Forging	Hammer forge Drop forge Sheet Steel press	32,000	

2.2 Metallurgical Plant - Donawitz

Plant Type	Plant Description	Capacity/year	Eng.
Sinter Plant	1 Sintering strand	1,430,000	VA
Blast Furnace	1 x 8m hearth diameter 1 x 7m hearth diameter	1,200,000	
LD Plant	3 x 60t	1,300,000	VA
Continuous Casting	1 Billet caster with 6 strands	380,000	VA
	1 Bloom caster with 3 strands	480,000	VA
Ingot & Slabs Mill	1 x 2 high reversing stand	465,000	
Billet Mill	Blooming Train 2 x 2 high stands Finishing Mill 6 x 2 high stands	316,000	
Section Mill	1 x 2 high reversing stand	108,000	
Section Finishing Mill	3 x 3 high stands 1 x 2 high finishing stand or a universal stand	219,000	
Bar Mill	9 Roughing stands 4 intermediate stands 4 finishing stands	175,000	
Wire Rod Mill	8 stand blooming train 2 x 10 intermediate stands 2 x 10 finishing stands	515,000	VA

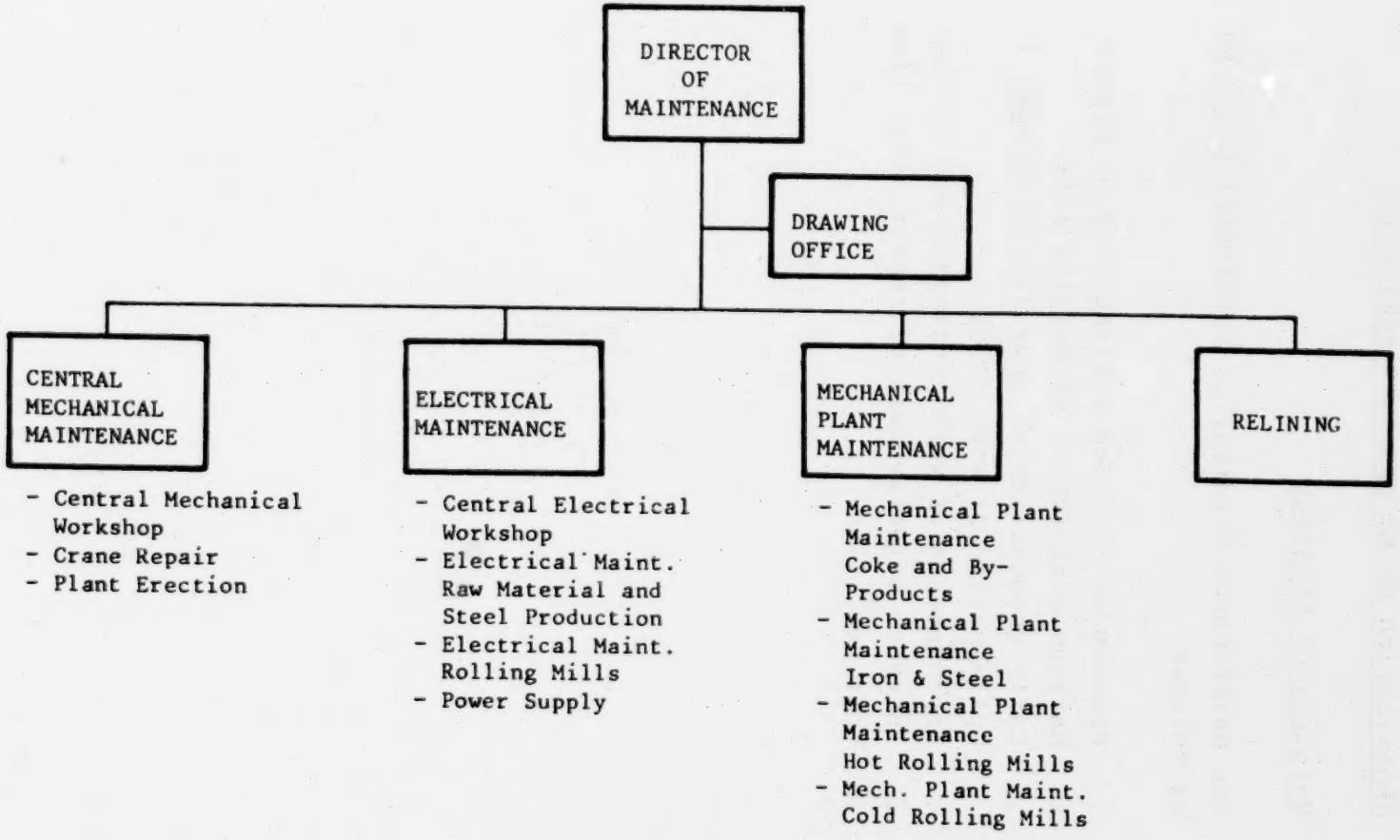
3. ORGANISATION OF MAINTENANCE ACTIVITIES

3.1 Maintenance Strategy

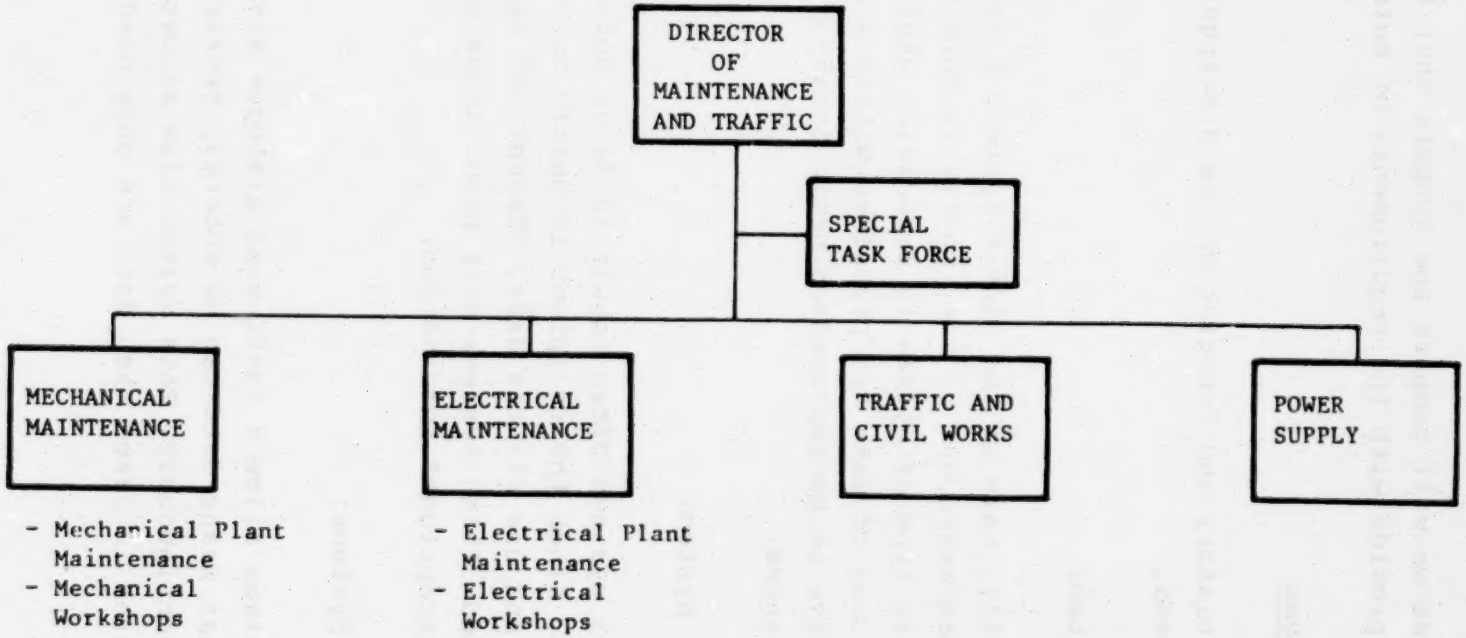
The maintenance strategy of VOEST-ALPINE can be summarised as follows:

- Production oriented availability of plants
- Maximum utilisation of service life
- Early recognition of approaching damages
- Optimisation of work plans
- Improvements of work monitoring and control
- Increase effectiveness of repair activities
- Cost reduction

3.1 Functions of Maintenance and their Organisation in the Linz Works


DIRECTOR OF MAINTENANCE
DRAWING OFFICE
CENTRAL MECHANICAL MAINTENANCE
- Central Mechanical Workshop
- Crane Repair
- Plant Erection
ELECTRICAL MAINTENANCE
- Central Electrical Workshop
- Electrical Maint. Raw Material and Steel Production
- Electrical Maint. Rolling Mills
- Power Supply
MECHANICAL PLANT MAINTENANCE
- Mechanical Plant Maintenance Coke and By-Products
- Mechanical Plant Maintenance Iron & Steel
- Mechanical Plant Maintenance Hot Rolling Mills
- Mech. Plant Maint. Cold Rolling Mills
RELINING

3.2 Functions of Maintenance and their Organisation in the Donawitz Works



4. AUTOMATION ACTIVITIES IN MAINTENANCE

In this chapter we will compare the support that EDP can economically provide with the requirements of maintenance.

Types of Systems

According to history and function we can distinguish various types of systems.

- Batch System:

  Historically, this is the oldest system. A large bulk of data is processed one by one, mostly in form of punch cards. This type of system is especially useful when large volumes of data are processed within a short time or data have to be reprocessed periodically with only slight changes.

- Exception System:

  Pure batch systems often result in large volumes of printouts. Since the recipient is hardly in a position to check and use all the data, "Exception" systems were implemented. These systems only print those lines which contain exceptional information.

- Dialogue Systems:

  These systems allow a continuous dialogue with the computer, that means data can be entered, retrieved and updated continuously. This system also allows the use of the computer in cases when data are only used a few

times. With this type of system new areas of applications were feasible.

- Analysis Systems:

  These systems allow the use of computer as a real tool to support decisions. Data available from applications are analysed, are used to simulate specific situations.

- Office Automation Systems:

  Here in the history of data processing it is no longer the data which are the centre of concern. The computerisation of all bureaucratic procedures is subject to the objective of the office computerisation. Therefore new fields are conquered by the computer which were previously closed to computers for economic reasons.

Functions in Maintenance and the Aptitude for Computerisation

Basically we can distinguish between three major functions in maintenance.

- Central Maintenance Workshop
- Plant Maintenance
- Spare Parts Management

Further on we will analyse these three functions to find out if they can be computerised and what type of systems might be appropriate for them.

- Central Maintenance Workshop

This function can be broken into the following subfunctions.

- Order Handling
- Job Preparation
- Scheduling
- Shopfloor Control
- Cost Control

One of the earliest areas of application in Central Maintenance Workshop was Cost Control. Of course these systems were batch systems. Their main objectives were to provide information on life-cycle costs of equipment. Other areas of application, which also started in the batch area, were scheduling. However, customers were not very pleased with batch scheduling systems, since their schedule algorithm was so strict that the computer calculated results which did not really meet customer's expectations. So only the recent possibility of implementing dialogue systems allowed an integrated solution of all functions of the Central Maintenance Workshop, providing the flexibility especially in scheduling expected by the user. So applications in the Central Maintenance Workshop are not too frequently found and we will be glad to be able to present you our solution a little bit later.

- Plant Maintenance

We are sure that by this stage of the meeting we will repeat certain facts which have already been discussed. However, to be able to analyse the usage of computers in plant maintenance we have to structure the function of plant maintenance. Subfunctions of plant maintenance are

. Servicing
. Inspection
. Repair

Concerning the subfunction Repair we have to distinguish between unplanned repairs, which are the result of a breakdown, and plant repairs which are the result of facts found during inspection. Since no large volume of data is valid for these functions, batch applications were not developed in this area. Forthcoming of dialogue systems now allows the cover of most functions of plant maintenance. However, the so-called unplanned repairs do not even meet the dialogue systems requirements. Unplanned repairs do not allow planning, are always very urgent. So in this area only the future office automation systems might be able to provide advantages.

For planned repairs nearly the same structure of subfunctions which was used above for Central Maintenance Workshop can be applied.

We are also pleased to be able to present you the system we use for planned maintenance.

- Spare Parts Handling

Although the spare parts handling could also be supported by a batch system, only a few implementations of spare part handling systems in batch were carried out in the batch area. The reason probably is that, in those days spare parts handling had no priority since a special feature of spare parts is that they belong to the slowest moving stocks. So data processing departments and users concentrated on the

fast moving consumables. In addition, requirements planning for consumables is much easier than for spare parts.

With the forthcoming of dialogue systems efforts concentrated mainly on implementing spare parts handling systems. Of course, VOEST-ALPINE also has a computerised spare parts handling system. Since it would overrun the available time, we are not going to speak in more detail about the spare part handling system.

In this chapter we only covered the computerisation of functions and subfunctions and not the possibilities of computerising single tasks. Such tasks like calculation of times, material requirements, etc. can also be computerised. Since also here the variety of possible computerisation would overrun the available time we refrain from touching it in more detail. In addition, EDP applications to computerise these tasks are hardly economic.

5. EXAMPLE: COMPUTERISED PLANNING AND CONTROL SYSTEM FOR CENTRAL MAINTENANCE WORKSHOP IN DONAWITZ WORKS

5.1 Volume of Activities

Productive hours per month: 45,000
Number of machines: 80
Number of non-mechanised working places: 210
Average number of active orders: 1,500
Total of order per year: 10,500
Number of operations per month: 4,500 - 6,000

5.2 Objective of the Project

The Project Team responsible for the execution of the computerisation of the planning and control in the Central Maintenance Workshop had to pursue the following objectives:

- Improvement of procedures and organisation structure in the Job Preparation Sector and on the Shopfloor aiming at an efficient treatment of orders, a proper functioning of scheduling and keeping deadlines.

- Inclusion of all orders in the Planning and Control System whereas the chosen software package should also be capable of supporting external orders.

5.3 The Situation at Project Start

At the time when the project started, 22 senior foremen controlled the Central Maintenance Workshop operation. No central scheduling or shopfloor control was available. No order handling was installed and the preparation of job cards was not frequently done. Planned times for each

operation were neither calculated nor estimated. The Central Maintenance Workshop operation relied strongly on the effectiveness of the cooperation of the 22 senior foremen. Therefore, no information was available about the present workload and obtainable target dates for the completion of the orders.

5.4 The Standard Software Package PS

Since it is company policy to use standard software packages whenever possible, we analysed available standard software packages for Production Planning and Control. This evaluation showed that the PS- System was best suited for this purpose, since it was the only package which supported make-to-order productions types. It is also the only system which allows implementation with incomplete data and data structures. The PS system is a modular system comprising all functions necessary to control operations.

From the modules of the PS System the following sub-modules were selected for implementation:

- Order Handling
- Bill of Material Processing
- Preparation of Job Plans
- Preparation of Shopfloor documents
- Assignment of work to each unit of the Shopfloor
- Shopfloor control and production data recording
- Cost Control

5.5 Functions of the System

For the purpose of easy system implementation we divided the system into 5 subsystems. In the following we describe the subsystems and provide some examples of VDU screen layouts and printouts.

- Subsystem "Order Handling":

  In this subsystem all orders received by the Central Maintenance Workshop are entered into the computer. The work to be performed following the orders can be distinguished as repair work, manufacturing of spare parts, the manufacturing of parts in extension and rehabilitation projects or manufacturing orders from external customers. Priorities can be assigned to each order.

- Subsystem "Job Preparation":

  This subsystem contains two major functions: Bill of Material Processing and Preparation of Job Plans. Once the Job Planner receives the Customer Order he checks if the necessary Bill of Material or Job Plan is already available in the system. This can be done either by checking according to the Job Plan number or the number of the drawing where the part or the assembly is contained. If he finds the Bill of Material or Job Plan he checks whether these documents can be used as they are or whether they have to be changed. If changes are necessary he can copy the Job Plan and make the necessary modifications. If the necessary Bill of Material or Job Plan is not available in the computer, the Job Planner

can enter the necessary data into the computer.

- Subsystem "Scheduling":

  The Job Scheduler receives information about each prepared Job Plan. He then schedules the Job Plan taking into consideration various facts such as priority, requested delivery date, available capacity, etc. The system thereby supports his decision with information which he can retrieve in a dialogue with the computer. After scheduling the Job Plan, the shopfloor documents are printed. A special feature in our printing of shopfloor documents is the printing of bar codes, which allow the entering of feedback information on the shopfloor using a barcode reader.

  An additional feature in the system is the automatic printing of purchase orders in the case where a certain operation has to be performed outside of the company.

- Subsystem "Shopfloor Control":

  The short term shopfloor control is done by the senior foreman.

  The following status can be reported using the barcode reader:

- Start of a job plan
- Start of an operation
- Completion of an operation
- Completion of a job plan
- Delivery to the customer

5.6 Project Schedule and Installed Hardware

Activity	Date
Decision	January 1983
Installation of Hardware	May 1983
Bill of Material Processing	August 1983
Job Planning	September 1983
Order Handling	October 1983
Scheduling	January 1984
Shop Floor Control	January 1984
Installation of Barcode Reader	April 1984
Start up of Barcoding System	June 1984

Installed Hardware

- DEC VAX11/750VMS

  12 VDUs
  2 Printers
  36 Barcode Readers

5.7 Benefits obtained by Implementing the System

After using the system for a large part of 1984 the following benefits can be assumed:

- Increase of Job Planners productivity

  The Job Planners increased the work they prepared by 100%. This tremendous productivity was partly achieved by reusing existing job plans and partly by simplifying the preparation process.

- Productivity increase of shopfloor personnel

  Compared with the situation before the implementation of the system, the amount of working hours required for the execution of the same order is now 15% lower. This reduction was achieved by improved work preparation, by the better provision of information. This led to a reduction of time required for waiting, being idle and transport.

6. EXAMPLE: COMPUTERISED PLANNED MAINTENANCE SYSTEM AS INSTALLED IN ZISCO, BAYOU AND THE VOEST-ALPINE WORKS, LINZ AND LIEZEN

6.1 Objective of the Project

The objective of all projects was the achievement of a higher plant availability by:

- Guaranteeing the execution of all maintenance activities to ensure a high plant service life

- Increasing the planning part of repairs to ensure

  - higher quality of performance
  - shorter performance times
  - shortest possible interference with production

6.2 Starting Situation

Longer term planning of repairs requires an exact knowledge of the condition of the plant. Thus it is necessary that all as critical defined plant parts are checked regularly. These inspections must be carried out by experts, who know the wear behaviour of the machine parts and their effects.

Furthermore, suitable organisation structures must be created which ensure the transfer of the known development of damage as a basis for the planning and realisation of the necessary measures.

6.2.1 Situation in the VOEST-ALPINE Works

The entire maintenance organisation in the VOEST-ALPINE Works was converted to planned maintenance in the 1960's, i.e.

- inspection units
- work preparation, and
- work control departments

were installed. At that time, due to the increased pressure of costs and the increasing technical complexity, it was no longer possible to place the responsibility for the security of the plants' availability on the experience of individual foreman. With the introduction of work distribution, based on an objective condition report, an exact work preparation could be carried out. The foreman's activities were then reduced to work control and monitoring according to preset plans.

The necessary servicing for guaranteeing the service life was traditionally a function of the plant personnel and is still carried out by plant personnel.

Since the planned maintenance was already carried out in the 1960's by VOEST-ALPINE, the transfer to EDP was carried out without any changes to the organisation. The objective of this transfer was not so much to increase the planning part but more the rationalisation and possibility of obtaining actual reports to improve decisions by the plant management.

6.2.2 Situation - Zimbabwe Iron & Steel Comp., Zimbabwe

Here the situation was marked by the distinctly low plant availability. An analysis showed, that neither maintenance nor repair planning was carried out on the necessary level. No structure and forms nor necessary experts were available. The condition of the entire plant was critical.

During this "operation improvement" project the following activities were undertaken following a step by step plan:

1) Repair of major weakness points of the plants during a "trouble shooting" mission

2) Increase of plant reliability by preparation of servicing instructions and controls
(e.g. drastic reduction in frequency of standstills)

3) Creation of the basis for repair planning by preparation of inspection instructions and deployment of inspectors; improved feedback from plant personnel achieved by introduction of "defect report cards".

4) Parallel to the introduction of servicing, inspection and defect reports, work preparation was installed and equipped with manual planning systems. Work control cards were introduced.

5) In the final phase the manual systems were replaced by a microcomputer supported system. The first area to be computerised was the wire rod mill. The heavy mill is planned as the next area.

6.2.3 Bayou Steel Corp., U.S.A

The project phases correspond to those of ZISCO. However, it must be mentioned that the plant has only been in operation for 2 years and the personnel had longer experience.

The entire operating plants were computerised after an acclimatisation phase with the manual system.

6.3 The Planned Maintenance Software Package

The system was developed for microcomputer. The reasons for this decision were:

- The higher degree of independency of the maintenance departments so that the additional expenditure for large computers had no advantages.
- The simplicity of the installation of this type of systems.
- The strategy to leave the responsibility with the user (my baby!)
- The low investment costs
- The possibility to integrate systems stepwise by means of linking
- The possibility to avoid complex solutions and to establish practical solutions which concentrate on the important issues.

We oriented the design of the programmes and the necessary organisation naturally to the experience of our maintenance departments. In spite of this, we made individual adaptations to client's requirements.

The package comprises the following standardised functions:

- Servicing
- Inspection
- Job Preparation
- Reports

Optionally, individual systems can contain the following functions:

- Preparation of orders for Central Workshops
- Spare part ordering of non-stock spares
- Capacity planning - personnel

The degree of detail of the individual functions also varies.

6.4 Functions of the System

- Subsystem "Servicing"

  This function records all periodic greasing jobs and determines the corresponding times.

  The feedback of the execution of the servicing is recorded in the system. For jobs not reported reminders are printed automatically.

Job cards are not printed for work carried out daily. This work is contained in lists which remain by the servicing personnel. The execution of this type of work is recorded for control purposes only.

It is recommendable to identify jobs especially which can be carried out during plant standstills. This allows the execution of such servicing during sudden plant standstills.

- Subsystem "Inspection"

This system is similar to the servicing subsystem. The instructions can be freely formed, however short standard formulations should be aimed at. Furthermore, statements regarding necessary tools, measuring devices and damage limits can be stored. Inspection cards with a feedback column can be printed, in which all results can be entered.

It is important to mention here, that the planning efficiency is decisively influenced by the inspection quality.

In many countries it is a problem to provide really good inspectors. These inspectors, as well as the Job preparers, should be experienced maintenance men. Resistance exists in many plants, when one tries to deploy well qualified maintenance personnel for these activities. Not only once we experienced that such personnel was used again for repair activities during the first major repair. This consequently resulted in a return to "trouble shooting" and a rapid deterioration of the availability.

- Subsystem "Job Preparation"

  In this system job cards are prepared based on inspections or damage reports. The degree of detail of this preparation fluctuates considerably. In the system in VOEST-ALPINE Linz the so-called repetitive repairs can be retrieved automatically. That means reference can be made to previous preparations, so the work involved is considerably reduced and the planning accuracy increases.

  Detailed repair instructions should never be stored because of the high costs involved.

  Required personnel should be stored according to trades and necessary spare parts included. Instead of a detailed work description only the work plan number and drawing numbers should be stored.

  Studies have shown how important accurate job preparation is and that up to 50% of the working time of maintenance personnel is unproductive. The reasons being lack of resources like tools, spares.

- Subsystem "Reports"

  a) Weakness Point Analyses

  Investigations by the TÜV have shown, that up to 50% of the total maintenance costs can be attributed to errors on the part of the manufacturer.

For diagnosis of weak parts, two different methods are distinguished:

1) By defining down the target service life:
   This method can show the weak points most precisely. A precondition for this is, of course, a realistic forecast of service life which production requirements takes into account (e.g. no excessive service life necessary, if parts can be changed easily during inevitable interruptions).

2) By defining down maximum frequency of damage:
   If insufficient information is available about the planned service life, the weak points have to be diagnosed from the frequency of failures. The problem here, of course, is that although a high frequency of failures is registered, the effects on production can, however, be minimal. Such plant components can not be designated as weak points, as the expenditure in reducing the frequency of failure probably does not give corresponding economical advantages.

   To be able to define weak points properly requires that the corresponding results of the damages (repair costs, down time) must also be registered.

Consequently, after defining weak points, the causes of damages have to be investigated. For this a detailed history of the effected elements must be available. Recommended alterations can concern the change of intervals of periodic instruction as well as alterations in construction.

6.5 Project Schedules and Hardware

ZISCO

1)	Decision to install PM system	11.83
2)	Analysis	12.83
3)	Software Adaptation	3.84
4)	System's installation (Delay of hardware delivery)	6.84
5)	Data Preparation	10.84
6)	Data Input	12.84
7)	Start of Operation	1.85

Hardware: WANG PC
Printer
Harddisc 15MB

BAYOU

1)	Decision to install PM system	6.83
2)	Start of manual system Rolling Mill	9.83
3)	Installation of computerised systems for the whole plant	9.84

Hardware: 2 Radio Shack TANDY Model 12
2 Line printers
2 Harddisc 12MB

VOEST-ALPINE - LIEZEN

1)	Decision to install computerised PM system	6.84
2)	Installation and Data Preparation	10.84
3)	Start of Operation	11.84

Hardware: HP-150
Harddisc 20MB
Printer

6.6 Benefits obtained by Implementing the Systems

Parameters for the economical assessment of the efficiency of maintenance plants are extremely problematic. As an example only the indicator of specific maintenance costs is quoted.

$$\text{Specific maintenance costs} = \frac{\$ \text{ Maintenance expenditure}}{\text{t Production}}$$

This indicator is influenced not only by the productivity during the service times but also by the maintenance economy. It can show a completely false picture of the actual situation.

At best the efficiency (not the economy!) can be shown on the basis of the plant availability.

However, one major problem is that causes of standstills as well as production errors are very often taken into consideration in the plant availability - so this picture is distorted.

6.7 Futural Aspects

6.7.1 Computerised Condition Monitoring Systems

A new development are computerised monitoring systems that are directly connected with the process equipment and steadily compare their measuring results with fixed damage limits. They are the inspection systems of the future.

These systems can be installed in existing plants, but due to the actual high costs they should be only used for most critical parts and points that can not be inspected with normal technology. We think that in future approximately 20% of the equipment will be monitored by omputerised systems.

As a step between normal inspection technology and fully computerised system, portable inspection equipment for analysing of temperatures, pressures, vibration, etc. have been introduced. This equipment is pre-programmed for its daily work by microcomputers and will play a decisive role in future.

Advantages of the system:

- reduced qualification of inspection personnel necessary
- subjective influences on the evaluation of feedback are reduced
- through trend analyses the development of damages can easily be forecasted
- through comparison of failure patterns with existing patterns the causes can be defined more detailed

- also very fast developing damages are timely reported

6.7.2 Maintenance Performance Measuring Systems

Today, availability analyses, time analyses, etc. are available to the maintenance managers. These evaluations, however, are not able

- to show a transparent picture of maintenance activities, which leads to much uncertainty about the necessity of the present level of effort for maintenance and the costs involved.

- to identify the real problems and their causes, so that many management decisions such as:

  . changes in the organisation
  . reduction or increase in staff
  . stock level reduction or increase
  . equipment of the maintenance shops, etc.

  are taken by instinct. It is also impossible in restrospect to check clearly the correctness of the decisions taken.

This problem of an unclear decision base is not new and not limited to maintenance organisations. Previously in the 1960's, performance measuring systems were developed which enabled the identification of factors influencing production and to vary these factors correspondingly.

A similar model for use in maintenance organisations has been developed at the University of Leoben, Austria.

About 50 parameters were defined and combined, so that statements on various situation of the maintenance department can be formulated.

How can this maintenance performance measuring system (MPMS) be applied?

If maintenance has to solve a problem, it can use the MPMS to find the parameters causing the problem and take the appropriate measurements. These measurements however, correspond now to the alteration of the one or more parameters (e.g. the alteration of the number of employees). The effect of this alteration on other parameters can now be simulated by the system. This simulation has the impact of the variation on other parameters.

If the computer supported system of the job planning section, which already possesses a large amount of necessary information, is now connected with MPMS on a second micro, a control instrument is obtained capable of making a large number of statements, that go far beyond the current management information.

What can such a report function offer?

A) All classical information of management information systems like:

- Immediate presentation of cost and time developments with an analysis of trends.
- Extensive support in preliminary preparation
- Precise graphic presentation of data for senior management
- Reduction in the manual, time-consuming preparation of topical reports and statements

B) Continuous control over deviations from targets and the ability for early correction.

C) Simulation of decisions and their results which should lead to much more proven decisions of management.

As there is still much potential for rationalisation also in our plants, the transfer of this management information and simulation model into a computer aided system has been given preference. In future we think that this system will become a second step of improvement in those client's plant, who already have installed well functioning planned maintenance.

6.7.3 Microcomputer Networks

The new generations of microcomputers offer the opportunity to link computers to one another. This offers the chance, to build up an integrated system step by step.

Especially a link to the warehouse system is very important. If the required spares are not available the whole process of job preparation cannot meet the objectives.

7. VOEST-ALPINE INDUSTRIAL SERVICES AND THE IMPORTANCE OF MAINTENANCE

The Business Objective of VAIS

VOEST-ALPINE, beyond being a producer of steel also engineers, supplies, erects and starts up metallurgical and chemical plants. In the early 70's VOEST-ALPINE was confronted with customers in the developing world who were not able to operate and maintain their new plants fully right from the point where they took over the turnkey plants. Besides the turnkey plants, this new type of customer required separate services which would enable them to operate and maintain the plant themselves. These services are

- Training of operation, maintenance and administration personnel
- Technical Assistance to operation and maintenance personnel
- Organisation structure and systems to operate, maintain and administrate the plant.

Since a well operated plant is a better reputation for us being a plant builder, and since we are also a plant operator we are able to provide these services. To provide these services effectively, an affiliated company, VOEST-ALPINE Industrial Services, was founded.

Clients problem with maintenance

Basically we distinguish between two types of clients in developing countries

- Clients whose major objective is to reach the rated capacity
- Clients whose major problem are in the cost of production

For the first type of client the identification and provision of spare parts is generally a great problem immediately followed by maintenance problems. Computerised planned maintenance can help to avoid unnecessary standstills and repairs which, due to lack of experience of the client's personnel, take a rather long time.

The second type of client has to reduce costs by increasing the productivity of his manpower. Computerisation in the Central Maintenance Workshop and Planned Maintenance can bring considerable cost reductions. This cost reduction is achieved by better utilisation of the employees' capacity, by increasing the life cycle of the equipment and by reduction of spare part costs.